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NASA AND NOAA STRATEGY FOR EESS DOWNLINK OPERATIONS IN THE 8025-8400 MHZ BAND

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Overview

- Objectives of NASA and NOAA
- Character of X-Band and Its Users
- Research Missions Evolving to Operations
- X-Band Strategies for the Future

Long-Term Objectives: NASA

- Emphasize planetary exploration (including Earth).
- Emphasize science research.
- Continue to focus on cutting-edge technology development.
- Transfer useful research/instruments/technologies to operating agencies.

Long-Term Objectives: NOAA

- Protect, restore, and manage use of coastal and ocean resources through ecosystem-based management.

- Understand climate variability and change to enhance society's ability to plan and respond.

- Serve society's needs for weather and water information.

- Support Nation's commerce with information for safe, efficient, and environmentally sound transportation.

Objectives Common to NASA and NOAA

- To responsibly share spectrum resources held in common with commercial interests.
- To not replicate commercially-available data, but purchase it.
- To promote the development of spin-off industries.
- To preserve data continuity in climate (and land) archives.
- To promote new observing techniques in space.

Utility of X-Band

- Is available to both public (government) and private (commercial) entities for remote sensing uses.
- Has mature technology with experience over many missions.
- Has both public and private infrastructure in place.
- Is available for geosynchronous orbit missions (e.g. by future NOAA GOES-R) and would provide uninterrupted observation of environmental parameters.

Utility of X-Band

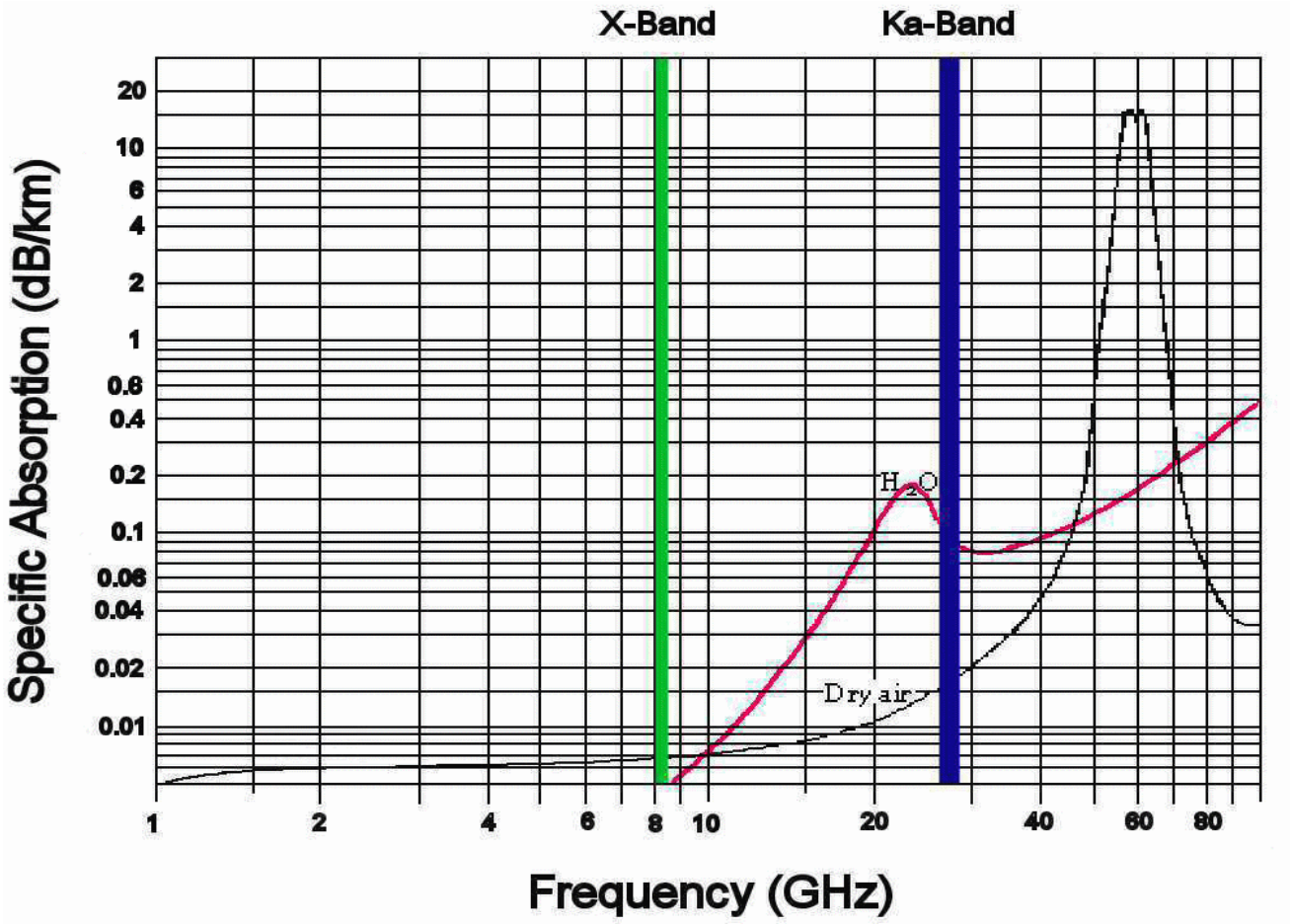
- Permits transmitting ~150 Mb/s to play back recorded data.
  - Possibly more depending on modulation, encoding schemes, and onboard compression.

- Experiences little rainfall attenuation (all-weather).

NOTE: Polar sun-synchronous orbits are very beneficial to Earth scientists who require the bandwidth available in X-Band:

- Entire-Earth coverage via Earth's rotation under orbit plane.
- Repeated, nearly same sun-angle observations.
- Few ground stations (2) needed for 1 playback/orbit.

Weatherliness of Bands



Ka-Band usage is problematic in the tropics.

X-Band User Characteristics

Service	Broadcast	Playback	Realtime
Bandwidth	< 20 Mb/s	100-150 Mb/s	~100 Mb/s
Transmitting	Continuously	Occasionally	Duty-cycle limited
Orbit	Sun-synchronous	Most sun-synchronous	Sun-synchronous
Ground Stations per Mission	96*	2-3	8 – 11
Number of Missions	~ 2	50-80	2 Landsats + ? commercial

* See: http://directreadout.gsfc.nasa.gov/links/eos-db_sites.cfm

U.S. Direct Broadcast Services

Future Usage	Instrument Broadcast	Frequency (GHz)	Datarate (Mb/s)	Launch
NOAA Series	APT	0.137	< 2.5 kHz	Dec. 1963, ongoing
NOAA Series	HRPT	1.7	0.67	Oct. 1978, ongoing
TERRA	MODIS	8.21	13.12	Dec. 1999
AQUA	All	8.16	15	May 2002
NPP	All	7.8	~12	Circa 2007
NPOESS	All	7.8	~20	Circa 2009, ongoing
NPOESS	VIIRS and other subsets	1.7	7	Circa 2009, ongoing

Direct Broadcast Stations

System	Users	Station Cost	Comment
NOAA - APT	~10,000	$500-$1000 + PC	Until ~ 2012
NOAA - HRPT	~ 2000	$15,000-$25,000	Until ~2012
TERRA/AQUA	~6	$500,000	1992 Estimate
TERRA/AQUA	96 +	$125,000	2005 Listing
NPP/NPOESS	~1000	< $125,000	2005 Estimate

NOTE: Modifying TERRA/AQUA ground stations for NPOESS should not be expensive due to the closeness of the EESS (8.2 GHz) and MetSat (7.8 GHz) bands.

NASA Research Can Benefit Operating Agencies

- US Geological Survey:
  - Landsat has evolved to an operational USGS mission.
  - EO-1 demonstrated technology for future use.

- NOAA:
  - Weather satellite technology developed by NASA is used in operational missions.
  - Aqua is considered the prototype of the next-generation of weather satellite, i.e. NPOESS.
  - TRMM and GPM are potential operational rainfall measurement missions.

AQUA Systems Evolve to NPOESS

Mission:	AQUA	NPP	NPOESS
Imaging Spectrometer:	MODIS	VIIRS	VIIRS
Microwave Sounder:	HSB & AMSU-B	ATMS	ATMS
IR Sounder:	AIRS	CrIS	CrIS
Broadcast:	8.2 GHz	7.8 GHz	1.7 and 7.8 GHz
Playback:	8.2 GHz	8.2 GHz	26 GHz

Instruments derived from those on AQUA will be demonstrated on NPP and flown operationally on NPOESS.

NPOESS Broadcasts are also known as low-rate data (LRD) at 1.7 Ghz and high-rate data (HRD) at 7.8 GHz;
NPOESS Playback is also known as stored mission data (SMD).

Strategy for the Future

NASA and NOAA:

- Will relieve X-Band congestion by moving to other bands when suitable:
  - technology is available and
  - infrastructure is in place, or
  - mission objectives change (e.g., from research to operational) and allocations permit.

- Will continue to use X-Band when necessary.

NASA's X-Band Strategy

- Use X-Band for stand-alone research and demonstration missions when driven by mission requirements.
  - Will use modern filtering and modulation techniques to minimize interference in- and out-of-band.
  - Will coordinate as time-space-frequency conditions require.

- Develop advanced technology to open new band(s) as needed.

- Use Ka-Band when technology and infrastructure are in place and mission requirements are met:
  - NPOESS, joint with NOAA.
  - Solar Dynamics Observatory.
  - Lunar Reconnaissance Orbiter.

NOAA's X-Band Strategy

Will remain in MetSat bands or other EESS bands unless they cannot meet mission requirements.

Examples: GOES Series
NOAA Series

NPOESS
- Playback will be in Ka-Band (300 MHz in 1.5 GHz).
- Broadcast will be in 1.7 and 7.8 GHz MetSat bands.

NOAA's X-Band Strategy

NOAA will use the EESS X-Band only when necessary to meet mission requirements.

Only example: GOES-R (bandwidth required ~150 Mb/s)

Concluding Remarks

NASA and NOAA recognize the usefulness of the EESS X-Band and, to promote its effective usage, will:

- Use other bands when suitable.
- Enable the use of new band(s) by advancing technology and building infrastructure.
- Use effective modulation and filtering schemes to avoid interfering with others.
- Coordinate closely with other band users when necessary .
- Strongly encourage other band users to be good stewards of this limited spectrum resource.

Backup Charts

Acronyms-1

Acronym	Mission or Instrument
AIRS	Atmospheric Infrared Sounder
AMSU-B	Advanced Microwave Sounding Unit-B
APT	Automatic Picture Transmission
AQUA	A mission focussing on the water cycle, also known as EOS PM-1.
ATMS	Advanced Technology Microwave Sounder
CrIS	Crosstrack Infrared Sounder
EESS	Earth Exploration Satellite Service
GOES-R	Geostationary Operational Environmental Satellite-R
GPM	Global Precipitation Mission
HRPT	High-Resolution Picture Transmission
HSB	Humidity Sounder from Brazil
MetSat	Meteorological Satellite

Acronyms-2

Acronym	Mission or Instrument
MODIS	MODerate -resolution Imaging Spectrometer
NASA	National Aeronautics and Space Administration (USA)
NOAA	National Oceanic and Atmospheric Administration (USA); also a series of polar-orbiting weather satellites.
NPOESS	National Polar-orbiting Operational Environmental Satellite System (USA)
NPP	NPOESS Preparatory Project
TERRA	The name of a mission focussing on the Earth's surface, also known as EO AM-1.
TRMM	Tropical Rainfall Measurement Mission
USGS	United States Geological Survey
VIIRS	Visible Infrared Imaging spectroRadiometer

Fire Fighting-1

Sentinel* is a fire detection system developed by Australians which:

- Provides the big-picture of fires across the country.
  - Helps fire emergency agencies allocate resources to areas needed.

- Uses MODIS data directly broadcast from Terra and Aqua:
  - Uses up to four down-links in a 24-hour period.
  - Identifies possible fires by looking for unusually high amounts of thermal and short wave infrared radiation detected by MODIS.
  - Creates a small file of hot spot indications which is then sent to interested parties/agencies in less than an hour of receipt.

- Is similar to U.S. MODIS Rapid Response Project which provides near real-time fire detection to National Interagency Fire Center in Salt Lake City, UT.

** from http://earthobservatory.nasa.gov/Study/Sentinel/sentinel.html*

Fire Fighting-2

MODIS data showing both immense plumes of smoke and the location of active fires (red dots). (Image acquired February 4, 2003)

Image showing fires detected around Canberra using Sentinel between January 14 and 17, 2003.

Fire Fighting-3

- Blackouts in MODIS X-band data posed problems for Sentinel:
  - Blackouts were scheduled to reduce possible RF interference with Deep Space Network stations (Canberra was one such station).
  - The nature of the 2003 Australian fire emergency required all MODIS data to be available.
- Problem was resolved when Deep Space Network personnel provided waivers to stop blackouts in most cases.

Fire Fighting-4

At sunset, smoke from bushfires approaching the Canberra Deep Space Network station in Tidbinbilla billows over a ridgeline near Mount Pleasant. Image courtesy of Fred Pilcher.

Fire Fighting-5

This experience proved the importance of 2 things:

- The usefulness of MODIS data and the direct broadcast system in preventing the loss of life and property by the

  - Identification of fires (MODIS data) and

  - Timely transmission of data (Direct Broadcast)

- The ability of spectrum managers to adjust priorities to societal needs.

Acknowledgements

- The discussion of the fire detection capabilities of TERRA and AQUA was drawn, with permission, from a paper by Angelita Kelley of NASA/GSFC entitled “Earth Science Morning and Afternoon Constellations” delivered at the International EESS Wideband Workshop held in Orlando, Florida in May, 2003.

- The user community size estimates were from a private communication from Patrick Coronado of NASA/GSFC.